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EFFECTS OF FERTILIZER TYPES ON MAJOR SOIL NUTRIENTS AND PERFORMANCE OF MAIZE (*ZEA MAYS* L.) IN ADO – EKITI, SOUTHWESTERN NIGERIA

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ABSTRACT

A two – year field experiment was conducted at the Teaching and Research Farm of the University of Ado - Ekiti, Nigeria, during early 2006 and 2007 cropping seasons to appraise the influence of fertilizer types on major soil nutrients and performance of maize (*Zea mays* L.). The experiment was laid out in a randomized complete block, with three replications. Treatments included: no fertilizer (NF) (control), inorganic fertilizer (IF), organic fertilizer (OF), and inorganic + organic fertilizer (IF + OF). The results obtained indicated that there were significant differences ($P \leq 0.05$) among the fertilizer types in growth and yield indices of maize. NF and IF decreased soil organic carbon (SOC) by 74 and 57%, respectively, contrasting increases of 31 and 18% for OF, and IF + OF, respectively. Similarly, NF and IF decreased total nitrogen (N) by 71 and 52%, respectively, compared to increases of 28 and 43% for OF, and IF + OF, respectively. The percentage decreases in available phosphorus (P) were 74 and 66% for NF and IF, respectively, as against increases of 33 and 54% for OF, and IF + OF, respectively. The two – year average values indicated that fertilizer types significantly increased maize leaf area from 0.52 m^2/plant for NF to 0.77, 0.67 and 0.92 m^2/plant for IF, OF, and IF + OF, respectively. Similarly, fertilizer types significantly increased maize grain yield from 1.93 t ha^{-1} for NF to 5.89, 5.21 and 6.32 t ha^{-1} for IF, OF, and IF + OF, respectively.

Keywords: maize yield, Fertilizer types, soil nutrients.

INTRODUCTION

One of the major constraints to crop production in the tropics is the inherently low fertility status of most of the soils, characterized by low levels of activity clay, organic matter, nitrogen, phosphorus and exchangeable cations (Gazel, 2005; Awodun and Olafusi, 2007). Since food production, a dependent factor of soil fertility, is the basic necessity of man, hence, the maintenance and improvement of soil fertility, which is critical to sustaining agricultural productivity and environmental quality for future generations are imperative (Awodun and Olafusi; 2007). The problem of soil fertility constraints to crop production in the tropics, which has been a major agricultural challenge over the years, has necessitated growing search for many soil fertility improvement techniques, such as the adoption of adequate fertilizer packages, involving the use of organic and/or inorganic fertilizers (Tankou, 2004; Awodun and Olafusi, 2007).

Although, the use of inorganic fertilizers in improving soil fertility has been reported to be ineffective due to certain limitations, such as declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation with resultant increased incidence of soil erosion (Awodun and Olafusi, 2007). Consequent upon this, the use of organic manure has been recommended, especially for highly weathered tropical soils (Tankou, 2004; Gazel, 2005; Awodun and Olafusi, 2007). However, the use of organic fertilizers has certain demerits of slow release and non – synchronization of nutrient release with critical period of growth for most short – term arable crops, as well as being required in large quantities to sustain crop production (Kiani *et al*., 2005). These problems, notwithstanding, many agricultural researchers (Adebo, 2004; Usor, 2005; Bai, 2007; Risse, 2007) have recommended the use of organic and/or inorganic fertilizers for improvement of soil fertility.

Maize (*Zea mays* L.) requires relatively high soil fertility, particularly nitrogen, phosphorus and potassium for high yield (Aitu, 2004; Veen, 2007). Significant responses of maize to fertilizer application have been demonstrated by many studies (Aitu, 2004; Caitt, 2005; Veen, 2007). In all these studies, significant increases in growth and yield of maize on application of both organic and inorganic fertilizers were reported. The significant response of maize to fertilizer application, perhaps, explains why it (maize) is often used as a test crop in many fertilizer trials (Caitt, 2005; Veen, 2007). However, too liberal application of fertilizers to maize, results in excessive vegetative growth and increased lodging (Aitu, 2004; Veen, 2007). Been *et al*. (2006), however, noted that the degree of responsiveness of maize to applied fertilizers, depends on the nature of the preceding crop(s). They concluded that where maize is preceded by soybeans, the latter is likely to have contributed about 30 – 50 kg N ha^{-1} to maize.

In Nigeria, one of the present – day principal constraints to food production is the depletion of soil fertility. In the past, farmers adopted bush fallow system to restore soil fertility, however, the system is no longer feasible due to increased population pressure, coupled with other competing demands for land. Consequent upon this, there is a dire need to conduct further research on other techniques of restoring soil fertility to increase yields in order to meet the ever increasing demand for food in Nigeria. To this end, this paper reports the results of a two – year trial, aimed at appraising the influence of fertilizer types on major soil nutrients and performance of maize.

MATERIALS AND METHODS

Study site

The two – year field experiment was carried out at the Teaching and Research Farm of the University of Ado - Ekiti, Nigeria, during early 2006 and 2007 cropping seasons. The soil of the study site belongs to the broad group Alfisols (SSS, 2002) of the basement complex. The soil was highly leached, with low to medium organic matter content. The study site had earlier been cultivated to a variety of arable crops, such as maize, cassava, melon, sweet potato, etc before it was left fallow for three years prior to the commencement of this study. The fallow vegetation was manually slashed, residues were burnt, and the land was ploughed and harrowed.

Collection and analysis of soil samples and organic fertilizer

Prior to planting, ten core soil samples, randomly collected from 0-15 cm, top-soils were mixed to form a composite, which was analysed for physical and chemical properties. At the end of the second cropping season, another set of soil samples was collected, and appropriately analysed. The composite samples were air–dried, ground, and passed through a 2 mm sieve. The sieved samples were then analysed. The pH was determined by glass electrode pH meter. Bray P – 1 extractant was used to extract available P, organic C and total N were determined by the Walkey – Black oxidation and Kjeldahl digestion techniques, respectively. Exchangeable bases – K, Ca, Mg and Na were extracted by neutral normal ammonium acetate. K, Ca, and Na were determined by flame photometry, while Mg was by Atomic Absorption Spectrophotometry. Effective cation exchange capacity was obtained by summation method (i.e. sum of K, Ca, Mg, Na and exchangeable acidity). The determination of exchangeable acidity was by extraction – titration methods, described by Mclean (1965). Particle size distribution was done by the hydrometer method of soil mechanical analysis, as outlined by Bouyoucos (1951). Total N in manure i.e. organic fertilizer was determined by the Kjeldahl method. Organic C was determined after dry combustion on an induction furnace after freeze drying. Potassium was determined by flame photometry after dry ashing, and solubilisation in 1M HCl. Phosphorus was measured colorimetrically after reaction with ammonium molybdo vanadate.

Experimental design and treatments

The experiment was laid out in a randomized complete block design, with three replications. The treatments included: no fertilizer (NF) (control), inorganic fertilizer (IF), organic fertilizer (OF) and inorganic + organic fertilizer (IF + OF). The organic fertilizer was a mixture of 5 t ha^{-1} composted sorted town refuse + 5 t ha^{-1} poultry droppings (Alabi, 2005). The inorganic fertilizer was NPK 15 – 15 – 15, applied at the rate of 400 kg ha^{-1}, at three and six weeks after planting (Fondufe, 1995). The inorganic + organic fertilizer was such that 200 kg ha^{-1} NPK 15 – 15 – 15 was added to 5 t ha^{-1} organic fertilizer (Alabi, 2005). The organic fertilizer was applied, two weeks before planting, worked into the soil with a hoe. The gross plot size was 6 m x 6 m, with 1 m margin round each plot.

Planting, collection and analysis of data

In 2006 and 2007, planting was done on April 3 and March 25, respectively. Seeds of Oba Super 1 maize variety, dressed with Apron Plus were planted on the flat, at 100 cm x 50 cm (20,000 plants ha^{-1}). Data were collected from five randomly selected maize crops from two central rows of each plot, in accordance with information for maize trial management in I.I.T.A's maize Research Programme pamphlet on growth and yield parameters. Leaf area was determined by finding the product of the length and breadth of the leaf, and then multiplying by a factor of 0.75 (Saxena and Singh, 1965). Stem diameter was measured by using venier caliper. Dry seed weight was determined by using a Metler weighing balance. All the data were subjected to analysis of variance, and treatment means were compared, using the Least Significant Difference (LSD) at 0.05 level of probability.

RESULTS

The physical and chemical properties of soil in the study site are presented in Table 1.

The soil was sandy loam in texture, with a pH of 5.2. The soil organic carbon (SOC) and total nitrogen (N) were 2.88 and 1.84 g kg^{-1}, respectively. The available phosphorus (P) was 1.71 mg kg^{-1}. The exchangeable bases – K, Ca, Mg and Na were 0.81, 0.75, 0.68 and 0.51 $cmolkg^{-1}$, respectively. The exchangeable acidity and effective cation exchange capacity were 0.28 and 3.03 $cmolkg^{-1}$, respectively.

Table 1: The physical and chemical properties of soil in the study site before cropping and nutrient composition of the organic fertilizer

Soil		Organic fertilizer	
Parameters	**Values**	**Parameters**	**Values**
Organic carbon (g kg^{-1})	5.2	Organic carbon (g kg^{-1})	1.91
Total nitrogen (g kg^{-1})	2.88	Total nitrogen (g kg^{-1})	0.81
Available phosphorus (mg kg^{-1})	1.84	Available P (mg kg^{-1})	0.48
Exchangeable potassium (cmol kg^{-1})	1.71	Exchangeable K (cmol kg^{-1})	0.58
Exchangeable calcium ($cmolkg^{-1}$)	0.81		
Exchangeable Mg (cmol kg^{-1})	0.75		
Exchangeable Na (cmol kg^{-1})	0.68		
Exchangeable acidity (cmol kg^{-1})	0.51		
ECEC (cmol kg^{-1})	0.28		
Texture (g kg^{-1})	3.03		
Sand	650		
Silt	218		
Clay	132		

Changes in soil nutrient status after cropping

Table 2 shows the influence of fertilizer types on major soil nutrients after cropping. NF and IF decreased SOC by 74 and 57%, respectively, contrasting increases of 31 and 18% for OF, and IF + OF, respectively. Similarly, NF and IF decreased total N by 71 and 52%, respectively, compared to increases of 28 and 43% for OF, and IF + OF, respectively. The percentage decreases in available P adduced to NF and IF were 74 and 66%, respectively, as against increases of 33 and 54% for OF, and IF + OF, respectively. NF and IF reduced exchangeable K by 64 and 43%, respectively, contrasting increases of 72 and 85% for OF, and IF + OF, respectively.

Table 2: Effects of fertilizer types on major soil nutrients after cropping

Treatments (Fertilizer types)	Org. C ($g\ kg^{-1}$)				Total N ($g\ kg^{-1}$)				Available P ($mg\ kg^{-1}$)				Exchangeable K ($cmol\ kg^{-1}$)			
	Initial	Final	*change	% change	Initial	Final	*change	% change	Initial	Final	*change	% change	Initial	Final	*change	% change
Control	2.88	0.75	-2.13	74	1.84	0.54	-1.30	71	1.71	0.44	-1.27	74	0.81	0.29	-0.52	64
Inorganic fertilizer	2.88	1.25	-1.63	57	1.84	0.89	-0.95	52	1.71	0.58	-1.13	66	0.81	0.46	-0.35	43
Organic fertilizer	2.88	3.78	0.90	31	1.84	2.35	0.51	28	1.71	2.27	0.56	33	0.81	1.39	0.58	72
Inorganic + organic fertilizer	2.88	3.41	0.53	18	1.84	2.63	0.79	43	1.71	2.63	0.92	54	0.81	1.50	0.69	85

* Change = Final - Initial

Maize leaf area

Maize leaf area, as affected by fertilizer types is presented in Table 3. The two – year average values indicated that fertilizer types significantly increased maize leaf area from 0.52 m^2/plant for NF to 0.77, 0.67, and 0.92 m^2/plant for IF, OF, and IF + OF, respectively.

Table 3: Effects of fertilizer types on maize leaf area.

	Maize leaf area (m^2/plant)						
	3 WAP		6WAP		9WAP		
Treatments (Fertilizer types)	2006	2007	2006	2007	2006	2007	Mean
Control	0.26a	0.23a	0.49d	0.44d	0.88d	0.83d	0.52
Inorganic fertilizer	0.26a	0.24a	0.74b	0.81b	1.30b	1.26b	0.77
Organic fertilizer	0.25a	0.26a	0.59c	0.62c	1.16c	1.12c	0.67
Inorganic + organic fertilizer	0.26a	0.25a	0.88a	0.93a	1.63a	1.58a	0.92

Values followed by the same letter in the same column are not significantly different at P=0.05.
WAP = Weeks After Planting.

Maize stem girth: Table 4 shows the effects of fertilizer types on maize stem girth. The two – year mean values showed that fertilizer types significantly increased maize stem girth from 1.74 cm for NF to 2.31, 2.12 and 2.38 cm for IF, OF, and IF + OF, respectively.

Table 4: Effects of fertilizer types on maize stem girth

	Maize stem girth (cm)						
	3 WAP		6WAP		9WAP		
Treatments (Fertilizer types)	2006	2007	2006	2007	2006	2007	Mean
Control	1.14a	1.10a	1.67d	1.59d	2.49d	2.43d	1.74
Inorganic fertilizer	1.14a	1.11a	1.99b	1.91b	3.88b	3.80b	2.31
Organic fertilizer	1.10a	1.12a	1.78c	1.74c	3.51c	3.46c	2.12
Inorganic + organic fertilizer	1.11a	1.13a	2.10a	2.06a	3.99a	3.91a	2.38

Values followed by the same letter in the same column are not significantly different at P=0.05.
WAP = Weeks After Planting.

Treatments (Fertilizer types)	3 WAP	
	2006	200
Control	1.14a	1.1
Inorganic fertilizer	1.14a	1.1
Organic fertilizer	1.10a	1.1
Inorganic + organic fertilizer	1.11a	1.1

Grain yield and number of days to 50% tasselling of maize: The effects of fertilizer types on grain yield and number of days to 50% tasselling of maize are presented in Table 5. Fertilizer types significantly increased maize grain yield from 1.93 t ha^{-1} for NF to 5.89, 5.21 and 6.32 t ha^{-1} for IF, OF, and IF + OF, respectively. The mean effects of fertilizer types on number of days to 50% tasselling of maize were 71, 65, 70 and 65 days for NF, IF, OF, and IF + OF, respectively.

Table 5: Effects of fertilizer types on grain yield and number of days to 50% tasselling of maize

	Maize grain yield (t ha^{-1})			Number of days to 50% tasselling		
Treatments (Fertilizer types)	2006	2007	Mean	2006	2007	Mean
Control	1.96d	1.89d	1.93	70a	71a	71
Inorganic fertilizer	5.91b	5.86b	5.89	65b	65b	65
Organic fertilizer	5.24c	5.18c	5.21	70a	70a	70
Organic + inorganic fertilizer	6.36a	6.28a	6.32	65b	65b	65

Values followed by the same letter in the same column are not significantly different at P=0.05.

DISCUSSION

The increase in SOC, total N, available P and exchangeable K that attended application of organic fertilizer and organic + inorganic fertilizers agrees with the findings of Tankou (2004); Gazel (2005); Awodun and Olafusi (2007) who noted significant increases in SOC, total N, available P and exchangeable K, following application of certain organic manures to the soil. This implies that, despite the removal of these nutrients (N, P and K) by maize from the soil system, however, a lot of them must have been released into the soil after the decomposition of the organic fertilizer, as organic fertilizers have been reported to be a store – house of plant nutrients (Kiani *et al*., 2005; Usor, 2005). Asides, the increase in N, P and K can be ascribed to reduced incidence of leaching of these nutrient elements, as the organic fertilizer may have improved the soil structure or aggregate stability, which in turn, may have resulted in increased nutrient – retaining capacity of the soil (Tankou, 2004; Bai, 2007).

The decrease in SOC, total N, available P and exchangeable K associated with NPK fertilization agrees with the findings of Adebo (2004); Usor (2005). This observation suggests that application of NPK fertilizer, unlike the organic fertilizer counterpart, did not result in build – up of soil nutrients (Adebo, 2004). The decrease in these soil nutrients, following NPK fertilizer application, is due perhaps, to the fact that application of NPK fertilizer may have resulted in the provision of favourable soil conditions for the action of soil microbial biomass with resultant increased rate of organic matter decomposition (Stewart, 1993). So, the depletion of soil organic matter (SOM), consequently resulted in the decrease in total N, available P and exchangeable K observed in the plots that received NPK fertilizer. This is because N, P and K, like other nutrient elements, are integrally tied to SOM, hence, maintenance of SOM is paramount in sustaining other soil quality factors (Jones, 2006). Much as the decrease in these nutrient elements can be adduced to the afore – mentioned factors, another factor that can be implicated for decrease in total N, available P and exchangeable K, resulting from NPK fertilization, is leaching of these nutrient elements, due to SOM depletion, as well as degradation of the soil physical properties (Usor, 2005). Although, application of NPK fertilizer has been reported to result in increased release of N, P and K into the soil, much of the released nutrients may have been lost to leaching during the rainy season (Awodun and Olafusi, 2007). The decrease in total N, available P and exchangeable K after cropping, despite NPK fertilizer addition, can be ascribed to exhaustive uptake of these three nutrient elements by maize, as there is always increased nutrient uptake by crops from inorganic sources of plant nutrients, since nutrients from these sources are more readily available, compared to organic sources counterpart (Gazel, 2005; Awodun and Olafusi, 2007). In view of the decreased SOC, total N, available P and exchangeable K that accompanied application of NPK fertilizer, to offset this short fall, hence, the recommendation of the addition of integrated organic and inorganic fertilizers to the soil is imperative.

The significantly higher values of growth and yield of maize treated with NPK fertilizer than those of maize treated with organic fertilizer agree with the reports of Aitu (2004); Caitt (2005); Veen (2007) who noted significantly higher growth and yield of maize treated with mineral fertilizer than those of maize treated with organic fertilizer. This observation can be ascribed to higher nutrient uptake by maize, resulting from the release of more nutrients by NPK fertilizer, since nutrients from inorganic fertilizers are more readily available to crops, compared to organic fertilizers counterpart (Aitu, 2004; Caitt, 2005; Veen, 2007). The best performance of maize associated with integration of organic and inorganic fertilizers agrees with the findings of Aitu (2004); Caitt (2005); Veen (2007). This observation suggests the superiority of combination of organic and inorganic fertilizers to other fertilizer types evaluated in this study. The superiority emanates from provision of more nutrients for maize by the integration of organic and inorganic fertilizers, as these two forms of fertilizers have been reported to complement each other, if and when combined (Aitu, 2004; Caitt, 2005; Usor, 2005; Veen, 2007). The superiority can also be explained in the light of the organic component of the mixture, playing a key role in sustaining desirable soil physical, chemical and biological properties, acting as a store – house of plant nutrients, as a major contributor to cation exchange capacity, and as a buffering agent against pH fluctuation (Tankou, 2004; Gazel, 2005). This implies that neither organic nor inorganic fertilizer alone is sufficient for satisfactory growth and yield of maize. Thus, the recommendation of an appropriate and adequate fertilizer package, involving a judicious and balanced combination of organic and inorganic fertilizers (i.e. fortification of organic fertilizer with mineral fertilizers) for maize cultivation is imperative (Usor, 2005;

Caitt, 2005). This is because nutrients, if and when supplied in the combined form (i.e. organic and inorganic sources combined) seem more efficiently utilized by crops (Usor, 2005).

CONCLUSION

Application of organic fertilizer, and organic + inorganic fertilizers resulted in an increase in SOC, total N, available P and exchangeable K. Conversely, addition of inorganic fertilizer resulted in a decrease in SOC, total N, available P and exchangeable K. The increase in growth and grain yield of maize associated with fertilizer types can be ranked as: NF < OF < IF < IF + OF.

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